Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 132 (2017) 592–597

Energy Procedia

www.elsevier.com/locate/procedia

11th Nordic Symposium on Building Physics, NSB2017, 11-14 June 2017, Trondheim, Norway

Analysis of reduction of energy demands for Zero Emission Renovated Office Building by using thermal mass and ventilative cooling

Maria Justo Alonso[a,*], Hans Martin Mathisen[b]

[a]*SINTEF Building and and Infrastructure, NO-7465, Trondheim, Norway*
[b]*Norwegian University of Science and Technology (NTNU), Kolbjørn Hejes vei 1b, NO-7491 Trondheim, Norway*

Abstract

Zero emission buildings (ZEB) are characterized by high levels of insulation and air tightness. Powerhouse Kjørbo is the first Zero Emission Renovated Office Building in Norway. In 2013-2014 the building from 1985 underwent a major renovation to passive house standard (class A), keeping only the concrete framework to reduce emissions. The building has been monitored for one year. The data has been used to build and validate an IDA ICE simulation model in order to study possible improvements in energy consumption by changing the thermal mass and the ventilation strategies.
The thermal mass effect is strongly dependent on the volumetric heat capacity and the thermal admittance. Thermal mass placement within the structure would modify the energy use for heating and cooling. For instance, placing the thermal mass in the internal walls will not have the same effect as placing it between the floors. The interaction with the ventilation system also affects the energy use. Using nighttime setback with heavy walls, (large thermal inertia) proves to reduce cooling demands during summer time. Other strategies of window control with heavy mass during daytime are studied focusing on reduced energy demands.
The conclusion for the studied case is that given that the concrete structure was already built, the use of thermal mass is smart. However, when designing to achieve ZEB, increase of thermal mass in the form of concrete must be thoroughly thought as it would decrease cooling demand and shift temperature peaks, but will not be so beneficial for heating. At the same time increased thermal mass will increase the greenhouse gas emissions.

Peer-review under responsibility of the organizing committee of the 11th Nordic Symposium on Building Physics.

Keywords: Thermal mass; Ventilative cooling; Thermal comfort; Energy use

* *Corresponding author. Tel.: +4794428591*
E-mail address:maria.justo.alonso@sintef.no

Peer-review under responsibility of the organizing committee of the 11th Nordic Symposium on Building Physics
10.1016/j.egypro.2017.09.750

1. Introduction

New buildings are to comply with more demanding requirements related to reduction of energy use. The use of thermal mass in these buildings with high insulation levels is much discussed. On the one hand, the thermal mass increases the building's inertia making it less responsive to sudden changes of outdoor temperature. On the other hand, a smart coordinated use of the thermal mass and the energy systems makes the building to become a thermal storage.

The thermal mass behavior is strongly dependent on its volumetric heat capacity (quantity of heat storage in the material) and its thermal admittance (quantity of heat transfer from material to air when subjected to cyclic variations in temperature). The depth of penetration of the diurnal heat waves' in the material depends on its thermal diffusivity [1]. If heat is stored beyond a certain thickness it would take longer to transfer it back to the indoor air. This would mean, in the worst case, that the heat would be released when heat demands are lower, incurring on increased cooling demands to dissipate the stored heat from the walls [1]. The concrete has low thermal mass diffusivity, which means it slows the heat transfer through the material; stores large amounts of heat; and is less sensitive to temperature differences in the surrounding environment.

Indoor lightweight materials exposed to sun will quickly heat up and transfer heat to the room air by convection. Heavy materials exposed to solar radiation will be able to absorb more heat without increasing their temperature, keeping the room air temperature constant[2]. Heat transfer coefficients for convective exchanges to and from the surfaces of the walls are greater for vertical walls than floors and ceilings[3], unless the room is ventilated by air diffusers near ceiling as then it becomes a radiant cooling surface.

The general assumptions for this paper are that (1) during cooling season the use of thermal mass stabilizes the internal temperature, which in turn, will reduce the building cooling demands [4]. In the evening, because of the evening air-temperature drop, night ventilation and thermal mass will easy remove heat accumulated in the building. The cooled mass is efficiently used to lower the building cooling demands only if the building envelope is well-insulated [1]. (2) During heating season, south-facing windows transmit solar radiation that will be stored in heavy thermal mass materials. When the solar radiation ceases, the stored heat will be released, reducing the heating loads[5]. (3) High thermal mass materials such as concrete could delay the internal temperature peak for several hours. Given a delayed temperature peak to after-work-hours and reduced heat gain, the required cooling energy decreases[5].

In this paper, based on measurements obtained from Powerhouse Kjørbo (PK), an IDA ICE model was developed to study the effect of thermal mass on energy consumption.

2. Measurements Powerhouse Kjørbo

Powerhouse Kjørbo is defined after the Powerhouse Alliance [6] as a building whose" *primary energy balance over its lifespan must be positive. Plus-energy implies that the building during its lifetime shall produce and export renewable energy that compensates for energy use for other life cycle stages. ".* In addition, it is the first Norwegian building renovated to ZEB-OM÷EQ level according to the definition of the Norwegian ZEB centre [7].

PK has a high-quality airtight building envelope with low average U-value and a VAV ventilation system with very low SFP factor and high-efficiency heat recovery from the extracted ventilation air and efficient solar shading. PK is equipped with an energy-efficient heating and cooling system with heat pumps. During the renovation of PK, the structural concrete constructions were maintained in order to reduce emissions due to materials.

During 15 days, temperatures were measured in (C, in Figure 1) ca. 8 meters away from the concrete walls in the middle of the open area at 1.2 m from the floor. Orientation Northeast. (D) on the concrete outside the ventilation shaft. 1.2 m from the floor. Orientation North-West. No excavation or scratching on the concrete surface was done. The occupancy and number of PC screens were measured from May 19^{th} to May 21^{st}; from Tuesday to Thursday.

Fig 1 shows the temperatures for this period for Sensor D on concrete wall and sensor C in the landscape. From these measurements, a delay between both measurements placed on the same room is seen. When employees come to work and the CO_2 concentration levels are not high enough to trigger the increase on ventilation rates, the temperature in the room increases. Meanwhile the temperature in the concrete is slowly rising but with a delay of almost two hours. Sensor C shows values for the open plan, which are up to 0.8 °C higher than the value for the same period on the concrete (at the beginning of the day).